REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AI	Approach Progress 6/1/94-5/30/95	
	May 18, 1995	Annual Prog		
4. TITLE AND SUBTITLE			5. FUNDING NUMBERS	
Josephson Sound in Superfluid Helium			PE61153N G N00014-94-0043 TA 312697002	
6. AUTHOR(S) Richard Packard				
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) The Regents of the Univeristy of California c/o Sponsored Projects Office 366 Sproul Hall. Berkeley, CA 94720-5940			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Research ONR 331 800 N Quincy Street Arlington, VA 22217-5660			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	

12a. DISTRIBUTION / AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

Approved for public release;
distribution unlimited

13. ABSTRACT (Maximum 200 words)

This project is directed toward detecting an acoustical field generated near a miscroaperture by quanitzed phase slip events in superfluid ⁴He. The annual report details the accomplishments of the past 12 months of this work.



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14. SUBJECT TERMS	15. NUMBER OF PAGES			
superfluid, Josep	3			
			16. PRICE CODE	
17. SECURITY CLASSIFICATION	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT	
OF REPORT	OF THIS PAGE	OF ABSTRACT	1	
unclassified	unclassified	unclassified	1	

Progress Report Grant # N00014-94-1-0043 Josephson Acoustic Radiation in Superfluid Helium May 1995

Brief Description

The goal of the project is to observe an acoustical field generated near a submicron aperture, which serves as the nucleation center for superfluid quantized phase slips. The investigators seek to demonstrate that the frequency of the acoustic signal is given by $f_j = \Delta P/\rho \kappa$ where ρ is the fluid density and $\kappa = h/m_4$, is the quantum of circulation.

Experimental Approach

The aperture is placed at one end of an acoustic resonator. Superfluid is forced through the aperture under a pressure head ΔP , a parameter which is monitored by a very sensitive pressure transducer. The resonant cavity is terminated with a sensitive cryogenic microphone.

Apparatus will be developed to push fluid at constant ΔP while the sound amplitude in the cavity is monitored.

Accomplishments During the Past Year

- 1. Preliminary tests indicated that small temperature changes created fountain pressure variations which would interfere with the constant pressure drive. Since fountain pressures decrease substantially with temperature, it was decided to design and construct a refrigerator to maintain the experiment below 0.3K. The adsorption pumped ³He cryostat was developed this year. The refrigerator met all design specifications and is now fully operational.
- 2. The Josephson frequency is directly proportional to the pressure head applied across the microaperture. Therefore the experiment requires a means of driving superflow at fixed pressure head. During the past year we developed a sophisticated active feedback system to permit constant pressure drive. Because the experimental path has extraneous Helmholtz resonances the feedback system requires several stages of phase shifts to maintain optimum regulation without oscillations. The design of the feedback system involved a close coupling of numerical design and experimental verification. The present design seems to meet our needs.

Although the constant pressure drive is successful we have noticed small variations in the driving signal that are not yet understood. We plan to investigate the source of these variations in the months ahead.

- 3. We have developed an improved version of a cryogenic valve which is required to isolated the acoustical chamber from the outside environment. The new design employs a beryllium copper seat which is hydraulically forced against a stainless steel ball. Although this design is superior to previous valves in our laboratory, we plan to improve it even further during the next year.
- 4. The constant pressure flow apparatus has been tested with a micro-aperture to see if the flow is limited by intrinsic phase slip processes. Preliminary data acquired thus far indicates that the flow is intrinsic which is the signature that phase slip events are occurring at the Josephson frequency.
- 5. In order to anticipate the spectral width of the Josephson acoustical signal it is very useful to understand the stochastic processes which are involved with the creation of individual phase slip events. It is these events that cause the individual pressure pulses that lead to the sound field.

Toward that end we developed a microfabricated silicon flow cell that permits the study of the phase slip process. The experiment has provided the first experimental determination of the phase slip energy barrier. The experiment led to the discovery that this barrier seems to be a universal function of superfluid Helium rather than some surface-specific function. This significant discovery will open the door to find the source of the universal mechanism.

Publications

- 1. Vortex Nucleation in Superfluid ⁴He, to be published in Phys. Rev. Lett., June 1995
- 2. The Determination of the Energy Barrier for Phase Slips in Superfluid ⁴He, J. Steinhauer, K. Schwab, Y. Mukharsky, J.C. Davis and R. E. Packard, To be published in J. of Low Temp. Phys., **100**, August 1995.
- 3. The Relationship Between the Josephson Frequency and the Arrhenius Rate for Vortex Nucleation in Superfluid ⁴He, J. Steinhauer, S. Backhaus and Richard E. Packard. Submitted to Phys. Rev. B.

Contributed Papers

American Physical Society, San Jose CA, March 1995,

- 1. A Rigorous Test of the Thermal Activation Model of Phase Slip Vortices in Superfluid ⁴He, J. Steinhauer, K. Schwab, Y. Mukharsky, J. C. Davis and R. E. Packard
- 2. The pressure dependence of the quantum-tunneling critical velocity in HeII, Y. Mukharsky, K. Schwab, J. C. Davis, J. Steinhauer and R.E. Packard
- 3. Fabrication and performance of a microfabricated superfluid oscillator, K. Schwab, J. Steinhauer, Y. Mukharsky, J.C. Davis and R.E. Packard

Conference on Quantum Fluids and Solids, Cornell University, Ithaca, NY, June 12-17,1995

- 1. A new technique for the measurement of intrinsic critical velocities in ⁴He, S. Backhaus and R.E. Packard
- 2. Recent Results with a Microfabricated Superfluid Oscillator, Keith Schwab and R. E. Packard

Invited Paper

Conference on Quantum Fluids and Solids, Cornell University, Ithaca, NY, June 12-17,1995

The Creation of Vortices in Superfluid ⁴He, Richard Packard

Students Associated With the Project

Scott Backhaus, graduate student researcher

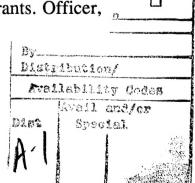
Keith Schwab, graduate student researcher, 25% time

Andrew Schecter, graduate student researcher supprted on AASERT supplement.

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